INVISCID AERODYNAMIC PREDICTIONS OF HYPERSONIC ELLIPTICAL PROJECTILES: A COMPARATIVE STUDY OF THE EFFECTS OF STABILIZING SURFACES

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With the advent of "smart" munitions, the U.S. and its allies are attempting to design more accurate tactical weapons. Of interest are relatively inexpensive barrel-launched projectiles capable of accuracy associated with guided munitions. This research studies potential configurations for a new class of kinetic energy projectiles.

From past research, it has been shown that projectiles with elliptical cross-sections are more stable in flight than those with circular cross-sections. This research looks at one particular shape, an elliptical cone, and numerically predicts the aerodynamic attributes in inviscid, steady, hypersonic flow. In particular, the effects of different stabilizing surface configurations are evaluated. A residual benefit of this research is to show that ZEUS, an afterbody solver typically used for missile design, is capable of providing solutions for these configurations.

The findings of this research will be delivered to the Chief, Aerodynamics Branch, Army Research Laboratory, and will fulfill part of ARL's commitment in a Key Technical Area agreement with the research laboratories of our allies.

DoD KEY YECHNOLOGY AREAS: Conventional Weapons, Modeling and Simulation

KEYWORDS: CFD, Inviscid, Aerodynamics, Hypersonic, Projectiles, Strakes, Flares

FORMATION CONTROL OF MULTI-SATELLITE SYSTEMS

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The concept of satellite formation has been studied in recent years as a method of improving high-resolution imaging capability. In contrast to the relatively simple single satellite model, a more innovative control mechanism must be developed for the purpose of stability and accurate synchronization of multi-satellite systems. A two-satellite system is adopted as our test model because the design criteria for both the multi-satellite and two-satellite systems are similar. To generate a more realistic appraisal of our model, random noise and unexpected errors are incorporated in the simulations. In addition to modeling, a formation controller is designed. Simulations are carried out to check the formation stability and the performance robustness in the presence of tracking error and measurement noise. All the simulations are based on Simulink.

DoD KEY YECHNOLOGY AREA: Command, Control, and Communications

KEYWORDS: Satellite, Formation, Control

AGE REPLACEMENT POLICIES IN MULTIPLE TIME SCALES

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We develop and estimate optimal age replacement policies for devices whose age is measured in multiple time scales. For example, the age of a jet engine can be measured in chronological time, the number of flight hours, and the number of landings. Under a single-scale age replacement policy, a device is replaced at age τ or upon failure, whichever occurs first. We show that a natural generalization to $k \geq 2$ scales is to replace non-failed devices when their usage path crosses the boundary of a k-dimensional region M, where M is a lower set with respect to the matrix partial order. For lifetimes measured in two scales, we consider two contexts. In the first, devices age along linear usage paths. For this case, we generalize the single-scale long-run average cost and estimate optimal two-scale policies. We show these policies are strongly consistent estimators of the true optimal policies under mild conditions, and study small-sample behavior using simulation. For the second context, in which device usage paths are unknown, we use two-dimensional renewal theory to derive the long-run average cost of a policy. We give examples in both settings and note that these ideas generalize to more than two scales.

DoD KEY TECHNOLOGY AREA: Other (Reliability)

KEYWORDS: Age Replacement, Multiple Time Scales, Renewal Theory

A BOUNDARY-LAYER MODEL OF THERMOCAPILLARY FLOW IN A COLD CORNER

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A pool of liquid with a horizontal free surface is bounded on one side by a vertical solid wall, which is maintained at a cold temperature relative to the core flow region. Strong temperature gradients along the surface give rise to surface tension variations (thermocapillary stress), which drives flow. Thin viscous boundary layers form along the surface and wall. A boundary-layer model is designed which captures the dynamics of the cold corner, applicable for any Marangoni number M and Prandtl number P in the convective inertial regime.

Analytical expressions for the velocity and boundary-layer thicknesses are developed, which allow accurate prediction of the flow field. The core flow region (outside the viscous boundary layers) is treated as irrotational flow and Laplace's equation is solved using both a Green's function approach and a complex variables approach in the quarter-plane. The flow along the wall is treated as a plane wall jet.

The two-dimensional unsteady heat equation is solved using an alternating direction implicit method. Results show that the flow into the corner is strong enough to contain the thermal field, compressing the isotherms along the wall after steady-state is reached. Additionally, a uniform stream function prediction is developed, by matching the inner and outer flows, giving a relatively accurate depiction of the flow.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures, Other (Applied Mathematics)

KEYWORDS: Thermocapillary Flow, Marangoni Number, Prandtl Number, Boundary Layer

AN EVALUATION OF HNeT (HOLOGRAPHIC QUANTUM NEURAL TECHNOLOGY) SOFTWARE PACKAGE

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This thesis investigates the properties of a software package called HNeT (Holographic/Quantum Neural Technology) which is based on the use of an artificial intelligence tool called Neural Networks. The basis for the investigation of this software is to establish its reliability, effectiveness and efficiency. Neural technology is a technological replication of the biological neural system designed to learn data patterns and process the data (stimulus) and then generate a response based on the memory of the data. HNeT theory is fundamentally different from the standard Artificial Neural System (ANS) in that it uses complex scalars to evaluate internal mappings of one set of values (stimuli) to another set of values (responses). HNeT employs a process known as *enfolding*, which allows the learning and subsequent recall of many stimulus-response associations to be compressed into a single HNeT neuron cell improving the speed of learning and recall accuracy as well as reducing storage requirements. Whereas the traditional ANS stores stimulus patterns separately as a reference template within a cell and are compared one at a time to a new incoming stimulus response pattern which in this case, requires larger amounts of memory.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Artificial Neural Networks, HNeT, Enfolding, Adaline, Madaline

MANUAL DIFFERENTIAL CORRECTION (MANDC)

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This thesis is a partial analysis of the Naval Space Command Manual Differential Correction (MANDC) software program. Through a process called Differential Correction, data collected from space surveillance radar observation stations is synthesized with previously composed element sets to maintain accurate orbital object position information. The Automatic Differential Correction (AUTODC) software program is central to this process. Unfortunately, AUTODC fails to converge 1.5% of the time. These failed observations are forwarded to MANDC for lengthy manual manipulation by the watchfloor operators. This thesis will provide an analysis of the MANDC program.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Nonlinear Least Squares, Differential Correction